

Market Potential Study for Water Heater Demand Management

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INTRODUCTION

Water heating represents between 13 and 17 percent of residential energy consumption nationwide.¹ Based on the 2007 Census data, roughly 42 percent of all homes in the U.S. have electric water heating; this equates to over 53 million homes. With such a high saturation of electric water heating nationwide, direct load control for water heaters has high potential for reducing peak demand, especially to help offset summer peaking driven by electric air conditioning use. One objective of this study is to quantify the possible savings from water heater curtailments aimed at reducing summer peak demands.

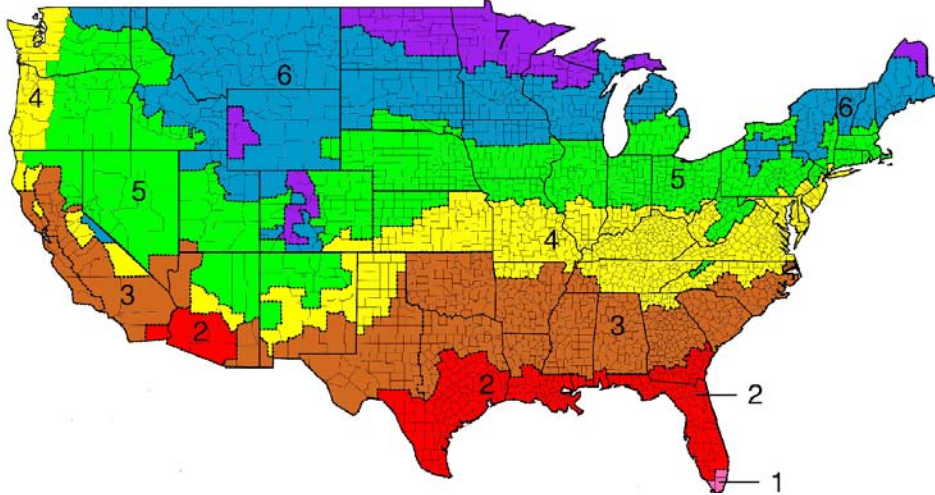
In addition to just cycling water heaters off during periods of high demand, water heaters could also be controlled to only operate during off peak hours. Utilities that have reduced off-peak generation costs could benefit from off-peak water heating programs. In addition, off-peak water heating programs could generate demand for renewable energy sources. For example, the state of Texas is a large producer of wind energy. In Texas, research has shown that the majority of wind energy is generated off-peak. By shifting electricity loads from on-peak to off-peak the demand for off-peak generation sources, such as wind energy, increases.

PEAK SAVINGS ESTIMATE FOR DIRECT LOAD CONTROL OF RESIDENTIAL ELECTRIC WATER HEATERS

The following analysis was conducted to estimate the peak demand savings potential for the one hour curtailment of hot water usage during the period of a utility's highest electrical demand. In order to quantify the potential savings, a per participant demand savings was determined using residential modeling software Energy Gauge USRRPB v2.8.01. To quantify the results, weather data was extracted for two representative cities from each of the weather zones represented in the International Energy Conservation Code (IECC). Due to their small population base, Zones 1 and 7 were not included in the evaluation.

¹ Energy Star Residential Water Heaters: Final Criteria Analysis – April 2008.

Figure 1: IECC Nationwide Climate Map²



The cities that were selected are displayed below with their corresponding IECC weather zone:

| IECC Weather Zone | Location |
|-------------------|------------------|
| 2 | New Orleans, LA |
| 2 | Jacksonville, FL |
| 3 | Dallas, TX |
| 3 | Sacramento, CA |
| 4 | Washington DC |
| 4 | Seattle, WA |
| 5 | Denver, CO |
| 5 | Albany, NY |
| 6 | Burlington, VT |
| 6 | Minneapolis, MN |

Energy simulations were conducted for each location to determine the electric water heating load profile and to determine the amount of water use and the ambient temperature in the garage or basement where the water heater would be located. The simulated home required a standard 50 gallon electric water heater with an energy factor (EF) of 0.90.³

² Building Energy Codes Resource Center

³ The federal standard energy factor for an electric water heater is 0.90 as of 1990.

The same generic house model was used for modeling each of the climate zones. The house configuration elements were as follows:

- Single family home
- Single story
- Three bedrooms, 2 bathrooms
- 1850 square feet
- Foundation: to reflect varying foundation types throughout the country, half the simulations were done with a slab foundation (more typical in southern climates), and half with a basement foundation (more typical in northern climates). Those simulations run with a slab foundation were: New Orleans, Jacksonville, Dallas, Sacramento, and Washington DC. Those simulations run with a basement foundation were: Seattle, Denver, Albany, Burlington, and Minneapolis.
- Existing insulation levels: R-19 ceiling, and R-10.26 in the walls
- Orientation: Square home with each of the four sides facing one of the cardinal directions with the same amount of window space on each orientation (window area is 10.2% of the conditioned floor space evenly split between each exterior wall of the home)
- 2 ft overhangs
- Roofing material: composite shingles – medium color
- Doors: wood
- Minimal or no shading was assumed as that will vary case by case
- Water heating: 50 gallon electric water heater located either in the garage (for slab foundation homes), or in the basement (for basement foundation homes)
- Space Cooling: 10 SEER unit
- Space Heating: Assumed to be either heat pump or electric resistance
- Thermostat settings: 68 for heating, 78 for cooling
- Duct losses: default setting of 15%

For the purposes of this study, the peak summer hour that was assumed to be the target of a curtailment event was the hour of 4pm to 5pm. Each of the hourly water heater load shapes for the various weather zones tested were reviewed for their simulation-assigned summer peak day, and at the hour of 4pm to 5pm. From the hourly water heater load shape data outputs, the average peak demand at the assigned hour for the 10 weather zones simulated was 0.40 kW. This average savings value indicates that a significant amount of peak reduction is possible through a water heater direct load control program. Table 1 below displays the annual energy use and demand outputs for a 50 gallon electric water heater from each weather zone analyzed.

Table 1: Electric Water Heater Annual Energy Consumption and Water Heater Summer Peak Demand for Each Location Analyzed

| Zone | Location | Annual Water Heater kWh Consumption | Summer Water Heater Peak Demand (hour ending 5pm) |
|-------------|------------------|--------------------------------------------|----------------------------------------------------------|
| 2 | New Orleans, LA | 2,675 | 0.29 |
| 2 | Jacksonville, FL | 2,671 | 0.31 |
| 3 | Dallas, TX | 2,837 | 0.28 |
| 3 | Sacramento, CA | 3,141 | 0.35 |
| 4 | Washington DC | 3,515 | 0.39 |
| 4 | Seattle, WA | 3,650 | 0.46 |
| 5 | Denver, CO | 3,636 | 0.43 |
| 5 | Albany, NY | 3,847 | 0.46 |
| 6 | Burlington, VT | 4,027 | 0.49 |
| 6 | Minneapolis, MN | 4,317 | 0.51 |
| | Average | 3,432 | 0.40 |

Participation Estimates for Direct Load Control

The National Assessment of Demand Response Potential study published by the Federal Energy Regulatory Commission (FERC) found that direct load control programs for residential central air conditioning could have participation rates as high as 25% without the benefit of any favorable pricing programs.⁴ With the addition of AMI, the study found residential participation rates in central air conditioning demand control programs to be between 19-100%.

Though the FERC study did not look at residential water heating demand control specifically, participation rates could be just as high or higher due to a less noticed impact on the customer’s comfort. A pilot study of direct load control for water heaters by the Portland General Electric Company found that customers participating in programs did not notice any difference in the availability of hot water during curtailments.⁵ Since

⁴ FERC study A National Assessment of Demand Response Potential: <http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf>

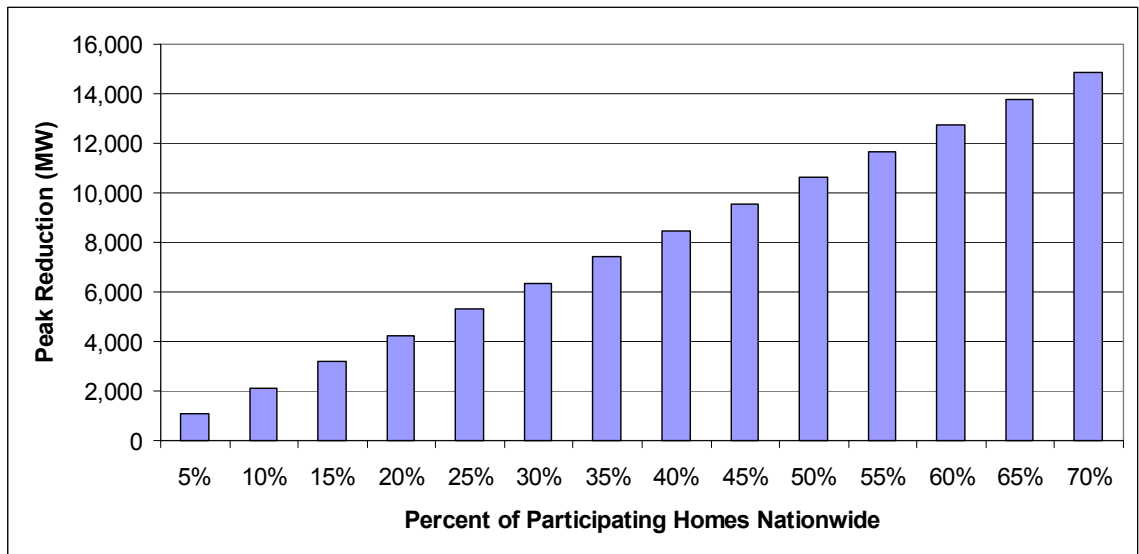
⁵ Direct Load Control Pilot for Electric Water Heat – Portland General Electric Company October 2004.

water heating does not have as direct of an effect on customer comfort as space cooling does, it might be reasonable to assume participation rates could reach as high as 25% or higher.

Potential Results of Water Heater Direct Load Control

There are roughly 53 million homes nationwide that have electric water heating.⁶ Potential peak demand savings based on various participation rates can be calculated given the estimated saving per unit of 0.40 kW. Figure 1 below displays potential peak demand savings for an electric water heater direct load control program. If a 25% participation rate was reached nationwide, as suggested by the FERC study (for air conditioning), the resulting savings would be about 5,300 MW of peak demand reduction, which equates to about \$424M (424 million dollars) in utility savings due to reduced on-peak generation needs.⁷

Figure 1: Peak Demand Savings Given Various Customer Participation Rates



Another beneficial component to water heater direct load control is “minimal kickback” (kickback implies the increased energy consumption seen in demand control programs that occurs post-curtailement as equipment comes back to its normal operating state). Creating minimal kickback also reduces the effects of peak shifting. Kickback is further reduced because water heaters are insulated, so there is minimal heat loss from the stored water over the assumed 1 hour of curtailment.

⁶ 2007 US Census Data – Home Characteristics.

⁷ Assumes savings of \$80 per kW of generation not needed at peak

POTENTIAL FOR EXTENDED CURTAILMENT PERIODS

Water heating curtailment also has potential for longer periods. Great River Energy in Minnesota offers their customers a water heater curtailment program with extended periods. Great River Energy offers customers two options, their Off-Peak Water Heating Program, or a Peak Shave Water Heating Program⁸. The Off-Peak Water Heating Program cycles high efficiency electric water heaters (with sufficient storage capacity) off over a 16 hour on-peak period. Customers participating in this program receive a special off-peak rate in return. The Peak Shave Program allows Great River Energy to interrupt customers during periods of high electric demand for up to eight hours per day. Customers that participate receive a special interruptible rate.

While the Peak Shave Water Heating Program acts similar to a typical direct load control program, the Off-Peak Water Heating Program is a load shifting program. The Off-Peak Water Heating Program permanently moves the demand of participants to off-peak periods on a year-round basis. Utilities that have reduced generation costs during off-peak could see considerable monetary benefits from this type of program.

Customers participating in the Off-Peak program must install water heaters with larger capacities, higher efficiency ratings, and high insulation levels in an effort to minimize the drop in water temperature during those periods of curtailment.

Great River Energy has had a high degree of success with these offerings. Table 2 below displays the participation rates and estimated peak demand savings achieved by the two programs.

Table 2: Participation and Savings Estimates for Great River Energy's Water Heating Curtailment Programs⁹

| | Peak Shave Water Heating Program | Off-Peak Water Heating Program |
|----------------------------------|-----------------------------------------|---------------------------------------|
| Strategy | Peak Reduction | Valley Filling |
| Number of Customers | 37,800 | 58,000 |
| Peak Reduction Capability | ~20 MW | 50 MW Year Round |
| Curtailment Period | 4-8 hours when curtailment is needed | 7am to 11pm (16 hours) Monday-Friday |

Renewable Energy Potential for Electric Water Heating

Electric water heaters also have the potential to efficiently utilize and build demand for renewable energy. Residential water heaters, unlike most home appliances and HVAC equipment, are effectively retaining or delivering hot water on a continuous year-round basis. Since they can be sufficiently modified such that they operate only during off-peak hours, the potential exists for them to be configured in such a way so as to utilize renewable energy generated off-peak.

⁸ http://www.greatriverenergy.com/projects/lines/wils_con.pdf

⁹ Great River Energy - Gary Connett

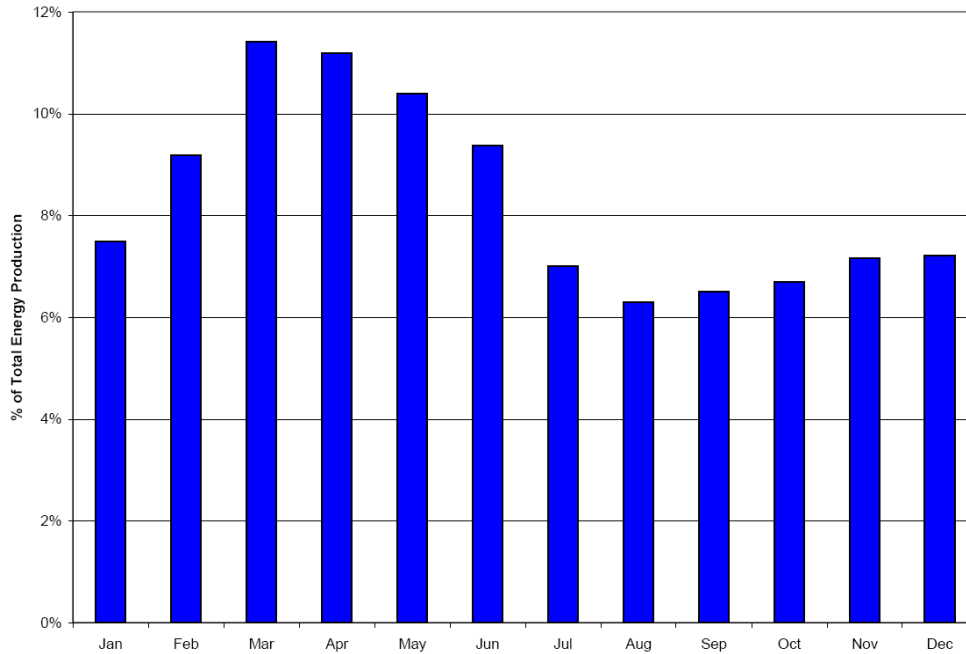
To accomplish renewable off-peak electric water heating, large-capacity/high-efficiency electric water heaters would require a dedicated device with temperature and voltage control capability connected to a utility-supplied load control switch or AMI device. These water heaters would be utility-controlled to only operate during off-peak hours. The water heater would need to heat stored water past the conventional set point, typically 120 degrees F, in order to meet the homeowners' hot water needs over the entire length of the utility on-peak schedule. To prevent the possibility of scalding water (water over 130 degrees) from reaching the faucet or showerhead, a thermostatically controlled mixing valve would need to be installed to mix cold water with the stored hot water to deliver water at the conventional 120 degree set point. For this type of application, only approved devices which fail to the cold setting should be approved for installation. Outfitting large-capacity, high-efficiency electric water heaters with the described controls would allow for the water heaters to be operated only during prescribed off-peak periods, and/or at times when renewable generation, such as wind, is occurring off-peak.

As mentioned earlier, Texas is a large producer of wind energy. Due to the volatility and swings in wind energy generation, it has more impact on longer-term use than on random net-load variations.¹⁰ Wind energy is not always correlated with loads, and wind generates more energy in the spring months and winter months. Figure 2 below displays annual wind generation in West Texas by month. Notice that wind generation is actually lowest during the summer peak months, indicating that wind energy could have high potential use for year round water heating. Shifting water heater electricity use from on-peak to off-peak could, in the long run, lead to greater demand for off-peak generation resources, such as wind power.

¹⁰ ERCOT Wind Impact/Integration Analysis Phase 2 Review Ancillary Services, February 1, 2008

Figure 2: Example of Monthly Energy Production for Texas Wind Farm¹¹

Monthly Energy Production – West Texas Wind Farm



CONCLUSIONS

Direct load control programs for electric water heaters have the potential to provide significant peak demand reductions across the nation. This would, in turn, provide reductions in peak generation costs incurred by utilities. For direct load control to be successful, all costs of implementing a program must be considered. Direct load control programs can be implemented with customers' existing electric water heating equipment, and would not necessarily require customers to invest in new, more-efficient electric water heaters. Therefore, the initial expenditures for this type of program would be the cost of the control switches and their installation, as well as any additional utility infrastructure costs.

While off-peak electric water heating programs have the potential to provide significant peak demand reductions, they can also serve to create higher demand for off-peak renewable generation, such as wind energy. As more wind farms are continually being constructed in Texas and around the country, the likeliness of the majority of their generation occurring during off peak hours should be considered in future utility demand response programs.

The success of off-peak water heating will be dependent on the cost benefits as well as the reliability of the equipment. Dedicated off-peak electric water heating typically requires customers to install larger-capacity, higher-efficiency electric water

¹¹ Integrating Wind into the ERCOT Market, Henry Durrwachter 11/11/08

heaters and additional controls. The cost benefits from the program must outweigh the incremental costs of an upgraded water heating system. An off-peak water heating program would be most beneficial for utilities that have high on-peak generation costs.